LANDSCAPE-SCALE LAND-COVER CHANGE AND LONG-TERM ABUNDANCE OF SCALED QUAIL AND NORTHERN BOBWHITE IN TEXAS

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ABSTRACT

Between 1978 and 1998, scaled quail (*Callipepla squamata*) abundance in the Rolling Plains ecological region declined ($r_s = -0.85$, $P < 0.001$), while no trend ($P = 0.74$) was exhibited in the South Texas Plains. Northern bobwhites (*Colinus virginianus*) exhibited no trend ($P > 0.10$) in either ecological region. Changes in land-cover between 1976 and 1998 indicated a loss of Savannah and Shrubland and an increase in Parkland cover types in the Rolling Plains. In the South Texas Plains, Woodland and Brush/Shrubland decreased between 1976 and 1998, whereas Brush/Shrub Parkland and Parkland increased. We examined land-cover change as a possible component in the scaled quail decline in the Rolling Plains. Loss of the Shrubland cover type may explain the decline of scaled quail in the Rolling Plains. Our results further suggest intraspecific spatial usability boundaries. These boundaries differed by species, with scaled quail associated with dense structure near the ground, whereas northern bobwhite were less abundant in areas dominated by scattered shrubs and trees, and large expanses of short, close-canopy cover types. A method is proposed for quickly obtaining data on land-cover changes on time.

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Key words: *Callipepla squamata, Colinus virginianus,* habitat, land-cover, northern bobwhite, regional abundance, scaled quail, Texas

INTRODUCTION

Populations of scaled quail and northern bobwhites have declined over the majority of their respective ranges during at least the last few decades (Brennan 1991, Church et al. 1993, Brady et al. 1998). In Texas, analysis of 21 years (1978–98) of quail abundance surveys conducted by Texas Parks and Wildlife (TPW) indicated both scaled quail and northern bobwhite abundance declined in multiple physiographic regions (Bridges 1999, Peterson 2001). In the Rolling Plains ecological region of Texas (Gould 1975), scaled quail abundance declined (Fig. 1), while no trend was exhibited for northern bobwhites (Fig. 2). In the South Texas Plains, no trend was exhibited for scaled quail or northern bobwhites. The short-term fluctuations in these surveys were weather related (Bridges et al. 2001).

Rollins (1996) listed brush encroachment as a possible cause of declining scaled quail abundance in Texas. Wilson and Crawford (1987) found scaled quail in southern Texas preferred sparser shrub cover than did northern bobwhites, while Reid et al. (1993) found scaled quail used both scattered shrub and thick shrub areas. In the Rolling Plains and South Texas Plains ecological regions, Reid (1977) found whistle-counts of northern bobwhites were negatively correlated with cropland and positively correlated with woody land-cover types. Reid et al. (1979) noted that in 3 of the

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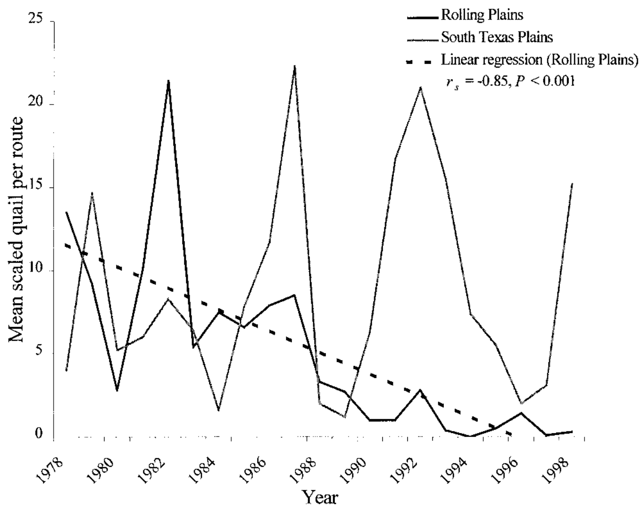

Fig. 1. Mean abundance of scaled quail per census route in the Rolling Plains and South Texas Plains ecological regions of Texas, 1978–98.

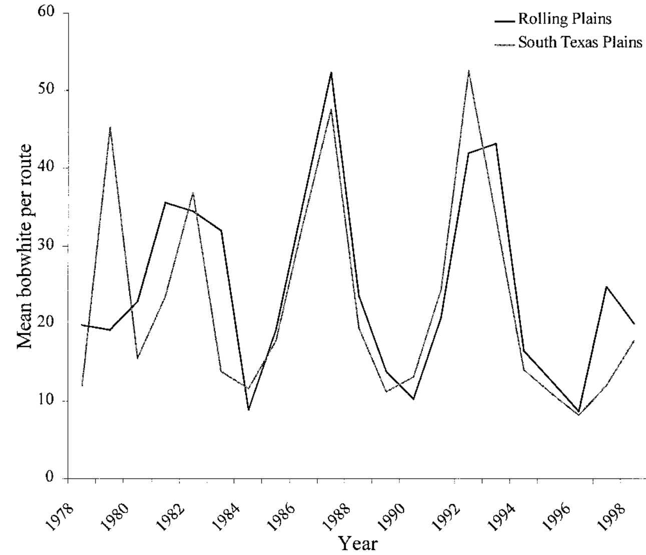

Fig. 2. Mean abundance of northern bobwhite per census route in the Rolling Plains and South Texas Plains ecological regions of Texas, 1978–98.

4 ecological areas (South Texas Plains, Edwards Plateau, Rolling Plains, and High Plains) of Texas where both species occurred, each species selected different habitats during the breeding season. In the fourth area, the High Plains, habitat use overlapped. The lack of adequate cover in the High Plains (76% cropland) suggested there was direct competition for habitat during the breeding season in this physiographic region.

Guthery (1997, 1999) proposed that northern bobwhites could sustain populations under a wide variety of habitat configurations, but thresholds exist after which usable space, and accordingly abundance would be affected. If a similar relationship between scaled quail and habitat exists, it might explain observed declines in abundance in the Rolling Plains of Texas.

For our study, we chose to look at quail populations in the South Texas Plains and the Rolling Plains of Texas. Northern bobwhite and scaled quail are more numerous (representing optimal habitat for both species) in the South Texas Plains than in any other ecological region of Texas (Bridges 1999). We chose the Rolling Plains because this is the only region in Texas where scaled quail are declining (representing unsuitable habitat for scaled quail).

The objectives of our study were to (1) evaluate changes in landscape-scale land-cover characteristics in the Rolling Plains and South Texas Plains ecological regions of Texas, (2) determine whether differential landscape-scale land-cover changes could have contributed to population trends of quail in the Rolling Plains and South Texas Plains of Texas, and (3) evaluate a vehicle-based method of land-cover classification for quantifying change.

METHODS

Land-cover surveys were conducted along TPW quail roadside census routes in the Rolling Plains and South Texas Plains ecological regions of Texas. The Rolling Plains is about 9,700,000 ha of the Great Plains extending south into Texas (Gould 1975:13). It is rolling terrain, primarily used as rangeland with some cropland, and ranges from 240 to 910 m in elevation. Annual precipitation ranges from 55 to 75 cm with peaks in mid spring and late summer. The South Texas Plains is approximately 8,000,000 ha of flat to gently rolling hills (Gould 1975:12). It is largely rangeland with some cropland and has an elevation varying from sea level to 300 m. Annual precipitation is 40 to 90 cm annually with peaks in late spring and late summer.

We used a 21-year (1978–98) quail abundance data set compiled by TPW. Biologists for TPW ran a series of 32.2-km census routes randomly placed throughout Texas (Peterson and Perez 2000). Routes were run annually during the first 2 weeks of August. Observations began either 1 hour before sunset or at sunrise. Observers drove at 32 km/hr and recorded quail species, total number seen (separated into singles, pairs, and coveys), and approximate age of quail at 1.6-km intervals.

The Rolling Plains and South Texas Plains ecological regions represented the western edge of the northern bobwhite's range and the eastern edge of the scaled quail's range in Texas (Reid 1977). On some routes in these regions, only 1 quail species was recorded from 1978–98. Therefore, all routes in these ecological regions might not represent suitable habitat for both quail species. If a quail species had never been recorded on a given route since its inception, that route was not considered habitat for that species and was excluded when calculating annual mean abundance per route for that species. To insure that biologically significant fluctuations (100% changes) in mean abundance could be detected from the data set, a power analysis (MINITAB 1998) was conducted revealing that doublings in mean abundance (100% change) between years could be detected in both ecological re-

Table 1. Descriptions of land-cover classes used in 1976 (Reid 1977) and 1998 land-cover surveys.

Land-cover class	Description
Barren	Areas with <25% ground cover.
Urban	Cities or towns; areas dominated by human dwellings including the fences, shrub rows, windbreaks, and roads associated with their presence.
Cropland	Cultivated cover or row crops used for food and/or fiber for man or domestic animals.
Pasture and fields	Areas dominated by grasses and/or forbs with <10% canopy cover of trees (single or multi-stemmed woody plants >3 m in height) and/or shrubs (single or multi-stemmed woody plants <3 m in height).
Shrub savannah	Pastures or fields with widely scattered shrubs covering 10–25% of the ground.
Shrub parkland	Pastures or fields with 25–75% canopy cover of shrubs, usually in clusters.
Shrubland	Evenly spaced shrubs covering ≥75% of the ground.
Brush parkland	Impenetrable clusters of shrubs covering 25–75% of the ground.
Brushland	A continuous, impenetrable cover of shrubs over ≥75% of the ground.
Tree savannah	Pastures or fields with widely scattered trees covering 10–25% of the ground.
Tree parkland	Pastures or fields with open or closed clusters of trees covering 25–75% of the ground.
Woodland	Evenly spaced trees (excluding managed fruit and nut trees), >3 but <10 m in height, covering ≥75% of the ground without understory.
Orchard	Managed, open stand of evenly spaced fruit or nut trees.
Forest	Trees >10 m in height, covering ≥75% of the ground and usually with an understory, except in managed monocultures.

gions at the ≥0.80 probability level ($\alpha = 0.05$; Bridges 1999).

Land-cover surveys were run during the first 2 weeks of August 1998. August was chosen to coincide with TPW survey timing. Surveys were run along TPW quail routes. For the Rolling and South Texas Plains, respectively, 35 and 27 routes were run. Exact route locations and maps were obtained from TPW. To evaluate changes in land-cover, a vehicle-based classification system developed by Grue (1977) and Reid (1977) was employed. One observer drove and read the odometer while a second observer evaluated and recorded land-cover types to approximately 0.8 km on both sides of the route (Table 1). Where more than 1 cover type was present within 0.8 km of the route, the cover type closest to the road was recorded.

Proportionate land-cover data from 1998 for the Rolling Plains and South Texas Plains were compared with land-cover data from the 1976 survey (Reid 1977). Routes run in 1998 generally overlapped with those run in 1976, but additional routes had been added by 1998 and all routes were 8 km longer than in 1976. Although routes were not identical, we considered both the 1976 and 1998 surveys to be sufficient to represent landscape-scale quail habitat at the time they were run.

Only major land-cover types (covering >2% of land) were used for further analysis. Because of the similarity of "brush" and "shrub" land-cover classes (as defined by Reid 1977), these classes were lumped by percentage of canopy closure into "Brush/Shrubland" and "Brush/Shrub Parkland" for further analyses.

Raw data collected in 1976 (Reid 1977) were not available, so detailed comparisons between individual routes were not possible. To analyze proportional data at the ecological region scale, Bonferroni confidence intervals ($\alpha = 0.05$) were constructed around major land-cover proportions for 1998 data. Means from 1976 were compared with this interval to determine whether significant changes in major land-cover types occurred between 1976 and 1998 surveys. Within the South Texas Plains ecological region, where scaled quail remained abundant between 1978 and 1998, routes were divided by those having a majority (defined as >1:1 ratio) of scaled quail versus northern bobwhite. This could not be done in the Rolling Plains because of the virtual extirpation of scaled quail from this region.

A modified version of the Bonferroni confidence intervals (Neu et al. 1974, Byers et al. 1984) was used to evaluate differences in land-cover. Sample size (n) was calculated by adding the total numbers of different habitat types recorded per route. For example, if 4 different habitat types occurred on the first route and 6 occurred on the second, then $n = 10$ for these 2 routes. Johnson (1999) recommended confidence intervals as an alternative to traditional hypothesis testing for wildlife studies. Cherry (1998) listed problems with using Bonferroni confidence intervals as *post hoc* tests for Chi-square analyses, arguing that if associated assumptions were met, confidence intervals were valid without Chi-square analysis. Additionally, sampling based on repeated locations of individual animals or repeated sightings of animals not known to be different might not strictly adhere to independence assumptions. The violation of the independence assumption, however, is routinely done in the literature (Neu et al. 1974, Byers et al. 1984). We considered the total number of different habitat types per route no less independent than multiple locations from 1 animal or repeated sightings of animals not known to be different.

Major land-cover types (barren, grain cropland, non-grain cropland, pasture, shrub savannah, brush/shrub parkland, brush/shrubland, savannah, parkland, woodland, and urban) significantly ($P < 0.05$) correlated with northern bobwhite and scaled quail abundance observed along transects during 1998 were identified from a matrix of product-moment correlation coefficients. Because so few scaled quail were observed in the Rolling Plains during 1998, we used the mean number of scaled quail seen during the period 1996–98 for correlation analyses of land-cover types and scaled quail in this ecological region. We assumed the major land-cover types seen along transects during 1998 had not changed significantly during this period.

Table 2. Bonferroni confidence intervals for proportions of major land-cover types adjacent to quail routes in the Rolling Plains ecological region of Texas in 1976 and 1998.

Land-cover type	Expected proportion (1976) P_{io}	Actual proportion (1998) P_i	% Change	Bonferroni intervals P_i
Cropland	0.339	0.297	−12.4	$0.217 \leq P \leq 0.377$
Pasture	0.208	0.203	−2.4	$0.132 \leq P \leq 0.273$
Shrub Savannah	0.139	0.049	−64.7	$0.011 \leq P \leq 0.087$ −
Brush/Shrub Parkland	0.038	0.117	207.9	$0.061 \leq P \leq 0.173$ +
Brush/Shrubland	0.042	0.020	−52.4	$0.000 \leq P \leq 0.044$
Savannah	0.104	0.022	−78.8	$0.000 \leq P \leq 0.047$ −
Parkland	0.059	0.188	218.6	$0.119 \leq P \leq 0.256$ +
Woodland	0.063	0.095	50.8	$0.043 \leq P \leq 0.146$

+ Indicates proportional increase in land-cover type at 0.05 significance level.
− Indicates proportional decrease in land-cover type at 0.05 significance level.

RESULTS

Land-cover Type Changes

In the Rolling Plains, Savannah (78.8%) and Shrub Savannah (64.7%) decreased between 1976 and 1998 (Table 2). Conversely, Parkland (218.6%) and Brush/Shrub Parkland (207.9%) increased during this period. Additionally, Brush/Shrubland (52.4%) decreased (nearly significant) in the Rolling Plains. In the South Texas Plains, Woodland (45.0%) and Brush/Shrubland (28.6%) decreased between 1976 and 1998 (Table 3). Brush/Shrub Parkland (256.4%) and Parkland (122.4%; nearly significant) increased and all other classes showed no significant change.

Ecological Region Differences

More Cropland (14.9%) and less Brush/Shrubland (−24.0%) existed in the Rolling Plains than in the South Texas Plains in 1998 (Table 4). On the 5 routes in the South Texas Plains dominated by scaled quail between 1978 and 1998, less cropland (−15.2%) and more Brush/Shrubland (33.8%) existed than on routes dominated by northern bobwhite in 1998 (Table 5).

Quail/Land-cover Type Relationships

During 1998, in the Rolling Plains, northern bobwhite numbers were positively correlated with Parkland (r = 0.391; P = 0.020), whereas scaled quail abundance was negatively correlated (r = −0.370; P = 0.029) with Grain Crops, positively correlated (r = 0.391; P = 0.021) with Savannah, and were positively correlated (r = 0.287) with Brush/Shrubland (although not significantly; P = 0.095). In the South Texas Plains, however, northern bobwhite abundance was positively correlated (r = 0.419; P = 0.042) with Pastureland and scaled quail numbers were positively correlated (r = 0.453; P = 0.026) with Brush/Shrubland. Although not significant (P = 0.108), northern bobwhite numbers were negatively correlated (r = −0.337) with Brush/Shrubland.

DISCUSSION

Changes in land-cover in the Rolling Plains between 1976 and 1998 indicated a loss of Savannah, Shrub Savannah, and Brush/Shrubland cover types, and a >200% increase in Parkland and Brush/Shrub Parkland cover types. In light of declines in scaled quail abundance in the Rolling Plains, it appears that scaled quail prefer areas of scattered shrubs and trees (nesting areas) and areas of thick shrubs (escape cover). This also is supported by their positive correlation with Savannah and Brush/Shrubland in the Rolling Plains. However, in 1998, the percentages of Shrub Savannah and Savannah land-cover types were higher in the Rolling Plains than in the South Texas Plains, where scaled quail populations were stable. It appears

Table 3. Bonferroni confidence intervals for proportions of major land-cover types adjacent to quail routes in the South Texas Plains ecological region of Texas in 1976 and 1998.

Land-cover type	Expected proportion (1976) P_{io}	Actual proportion (1998) P_i	% Change	Bonferroni intervals P_i
Cropland	0.193	0.148	−23.3	$0.080 \leq P \leq 0.216$
Pasture	0.117	0.123	5.1	$0.060 \leq P \leq 0.185$
Shrub Savannah	0.029	0.037	27.6	$0.001 \leq P \leq 0.073$
Brush/Shrub Parkland	0.055	0.196	256.4	$0.120 \leq P \leq 0.272$ +
Brush/Shrubland	0.364	0.260	−28.6	$0.175 \leq P \leq 0.344$ −
Savannah	0.035	0.023	−34.3	$0.000 \leq P \leq 0.052$
Parkland	0.049	0.109	122.4	$0.0492 \leq P \leq 0.169$
Woodland	0.160	0.088	−45.0	$0.027 \leq P \leq 0.132$ −

+ Indicates proportional increase in land-cover type at 0.05 significance level.
− Indicates proportional decrease in land-cover type at 0.05 significance level.

Table 4. Bonferroni confidence intervals for proportions of major land-cover types adjacent to quail routes in the Rolling Plains and South Texas Plains ecological regions of Texas in 1998. RP = Rolling Plains and STP = South Texas Plains.

Land-cover type	Rolling Plains	South Texas Plains	%Difference (RP-STP)	
Cropland	$0.217 \leq P \leq 0.377$	$0.080 \leq P \leq 0.216$	14.90%	RP > STP
Pasture	$0.132 \leq P \leq 0.273$	$0.060 \leq P \leq 0.185$	8.02%	
Shrub Savannah	$0.011 \leq P \leq 0.087$	$0.001 \leq P \leq 0.073$	1.26%	
Brush/Shrub Parkland	$0.061 \leq P \leq 0.173$	$0.120 \leq P \leq 0.272$	−7.89%	
Brush/Shrubland	$0.000 \leq P \leq 0.044$	$0.175 \leq P \leq 0.344$	−23.98%	RP < STP
Savannah	$0.000 \leq P \leq 0.047$	$0.000 \leq P \leq 0.052$	−0.14%	
Parkland	$0.119 \leq P \leq 0.256$	$0.049 \leq P \leq 0.169$	7.87%	
Woodland	$0.043 \leq P \leq 0.146$	$0.028 \leq P \leq 0.132$	1.47%	

RP > STP Indicates proportionally more land-cover on the Rolling Plains at 0.05 significance level.
RP < STP Indicates proportionally less land-cover on the Rolling Plains at 0.05 significance level.

that nest sites are not limiting in the Rolling Plains. This was not true for escape cover (Brush/Shrubland), which comprised only 2.0% of total land-cover in the Rolling Plains and 26.0% of total cover in the South Texas Plains. The 52.4% decline of this cover type, from 4.2 to 2.0% of the total area of the Rolling Plains, may be below the lower threshold of this cover type required by scaled quail, thus precipitating the decline observed in the Rolling Plains. Furthermore, and contradicting Wilson and Crawford (1987), scaled quail were found in greater proportional abundance on routes in the South Texas Plains with more dense woody land-cover than on routes with less woody land-cover. This is further illustrated by the positive and negative correlations between Brush/Shrubland and scaled quail and northern bobwhite abundance, respectively, in the South Texas Plains. Because northern bobwhites were associated with Parkland cover types (Parkland increased over 200%) in the Rolling Plains, their populations remained stable. Apparently, the increase in Parkland was above the threshold required by northern bobwhite for this cover type.

Scaled quail and northern bobwhites do not have identical land-cover requirements (Schemnitz 1964, Reid et al. 1979, Wilson and Crawford 1987). Thus, differential trends in scaled quail and northern bobwhite abundance within the Rolling Plains should not be surprising. Campbell et al. (1973) found that a dense understory of forbs and shrubs was not optimal scaled quail habitat. Brown (1989:145) advocated clearing dense brush on hilltops to improve scaled quail habitat. Schemnitz (1964) found scaled quail preferred less dense cover than northern bobwhites. Wilson and Crawford (1987) also found that scaled quail preferred relatively sparser shrub cover than did northern bobwhites, suggesting that moderate densities of woody land-cover might adversely affect scaled quail while not harming northern bobwhites. However, Reid et al. (1979) noted scaled quail selected shorter shrub types with more closed canopies, whereas northern bobwhites were located in more open, taller, and diverse types.

Our results suggest both quail species have maximum and minimum limits (habitat boundaries) in their habitat preferences. Guthery (1997) argued that usable space was limiting for northern bobwhites. Although distance to woody mottes limited habitat usability in Guthery's (1999) northern bobwhite model, he did suggest a second boundary after which woody land-cover could become too dense and availability of herbaceous land-cover might be limiting. It appears the discrepancies in cover-type use found by various investigators can be explained by the concept of both a lower and upper boundary of canopy closure for both northern bobwhites and scaled quail. However, these boundaries apparently differ by species, with scaled quail preferring dense structure near the ground (scattered shrubs and/or trees that allow dense grass or forb understory or dense shrubs that produce a dense understory). Such habitat is produced by Shrub Savannahs, Savannahs, and Brush/Shrublands, all of which were correlated with scaled quail numbers in our study. Northern bobwhites prefer (correlated in our study) Shrub Parkland, Parkland, and Woodland types

Table 5. Bonferroni confidence intervals for proportions of major land-cover types adjacent to quail routes in South Texas Plains ecological region in 1998 dominated by either scaled quail or bobwhite from 1978 to 1998. Scaled = scaled quail and Bob = northern bobwhite.

Land-cover type	>50% Scaled quail	>50% Bobwhite	%Difference (RP-STP)	
Cropland	$0.000 \leq P \leq 0.0964$	$0.0965 \leq P \leq 0.259$	15.21%	Scaled < Bob
Pasture	$0.000 \leq P \leq 0.147$	$0.066 \leq P \leq 0.214$	9.12%	
Shrub Savannah	$0.000 \leq P \leq 0.110$	$0.000 \leq P \leq 0.078$	0.66%	
Brush/Shrub Parkland	$0.026 \leq P \leq 0.399$	$0.108 \leq P \leq 0.275$	−2.05%	
Brush/Shrubland	$0.306 \leq P \leq 0.760$	$0.111 \leq P \leq 0.279$	−33.84%	Scaled > Bob
Savannah	$0.000 \leq P \leq 0.059$	$0.000 \leq P \leq 0.059$	1.46%	
Parkland	$0.000 \leq P \leq 0.156$	$0.053 \leq P \leq 0.192$	6.89%	
Woodland	$0.000 \leq P \leq 0.196$	$0.023 \leq P \leq 0.138$	0.47%	

Scaled > Bob Indicates proportionally more land-cover on scaled quail routes at 0.05 significance level.
Scaled < Bob Indicates proportionally less land-cover on scaled quail routes at 0.05 significance level.

(where shrubs or trees are clumped, with understory being open) and open grass or forbs types nearby. Northern bobwhites appear to avoid totally open areas with only scattered shrubs and trees and large expanses of short, close-canopy cover types.

Cropland (negatively correlated with scaled quail abundance) was more prevalent on the Rolling Plains than on the South Texas Plains in 1998, providing support for the hypothesis that changes in agricultural practices such as ''clean farming'' might be detrimental to scaled quail (Schemnitz 1993; Brady et al. 1998). Scaled quail also were found in greater proportional abundance on routes with less cropland in the South Texas Plains in 1998. The decline in scaled quail abundance in the Rolling Plains also supports this hypothesis, while the lack of long-term trend in northern bobwhite abundance does not. However, scaled quail were more abundant on routes with significantly less cropland than those dominated by northern bobwhites in the South Texas Plains, indicating that cropland in 1998 might not be suitable habitat for scaled quail.

MANAGEMENT IMPLICATIONS

Our study suggests that quail habitat boundaries are species specific and non-linear. If this is the case, efforts should be made to understand spatial-temporal habitat parameters and boundaries for regional populations of individual quail species. After establishing these boundaries, management efforts should focus on maximizing spatial-temporal usability (Guthery 1999). Our study also illustrates a method for quickly documenting land-cover changes and the potential importance of such changes for managing wildlife. Capel et al. (1993) listed the development of inventory and monitoring systems for quail habitat as a needed component of strategies designed to reverse quail declines. While not a substitute for remote sensing analysis, methods similar to ours might provide a convenient and inexpensive alternative for evaluating land-cover changes. After baseline land-cover surveys of road censuses have been conducted, the periodic re-running of the surveys, easily conducted in conjunction with wildlife abundance surveys, could allow for quick and inexpensive evaluation of land-cover change. If further investigation is necessary, survey results also might provide valuable ground-truthing data for remote sensing analysis.

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